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Fatigue Life Analysis of Annular BOP Shell with Eccentric Wear Defect

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Abstract

The annular blowout preventer is impacted by the high pressure oil and gas in the well during its operation, and the shell may produce cracking cracks at the stress concentration part under the fatigue damage and periodic load, and the expansion in the long-term service will lead to the sudden fracture of the blowout preventer shell and fatigue damage. In order to analyze the factors affecting the fatigue life of annular BOP shell under eccentric wear damage, the initial defects of different shapes were applied to the FH35-35/70 annular BOP shell made of 25CrNiMo material, and its fatigue life was simulated.

Keywords

Annular BOP; Eccentric Wear; Fatigue Damage; Fatigue Life.

1. Introduction

The shell is the main support of the annular blowout preventer, and its structure directly determines the structural safety of the annular blowout preventer. In the service process of annular blowout preventer, when overflow occurs in the well and forced shut-in is required, due to excessive pressure in the well, forced shut-in will produce high-pressure oil and gas, and the blowout preventer is subject to high-pressure impact load. Due to the continuous attenuation and propagation of high-pressure shock wave energy in the well, the shell may produce cracking cracks at the stress concentration part under the effect of fatigue damage and impact load. Especially when the working load is large and the number of switching cycles is large, fatigue cracks will appear on the outer surface of the annular blowout preventer, resulting in fatigue fracture of the shell. If the load is too large and large stress is generated in the shell stress concentration area, the annular blowout preventer is likely to break at many places. The eccentric wear damage will lead to the stress concentration area of the annular BOP shell, so it is necessary to analyze the fatigue life of the annular BOP shell under the eccentric wear damage defect.

2. Establishment of Annular BOP Model with Eccentric Wear Defect

Assuming that the worn part is located at the drift opening of the lower shell of the annular blowout preventer, the physical model of the annular blowout preventer after eccentric wear is established. As shown in Figure 1, the constraint and loading conditions of the model are that both ends of the blowout preventer are fixed, the left and right sides are symmetrically constrained, and the inner wall is subjected to a uniform internal pressure of 35MPa.

The friction surface on the drift diameter wall of the blowout preventer is regarded as a semi-elliptical surface with concave middle and flat sides, and the wear surface with defect length of 150 mm and defect depth of 2 mm is prefabricated as shown in Figure 1. Other structural parameters are shown in Table 1. In order to facilitate calculation and omit some small structures, such as lifting lugs, sealing grooves, connecting threads of top cover and shell, the

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BOP shell is a symmetrical rotating body, and 1/4 of its structure is taken for modeling and analysis.

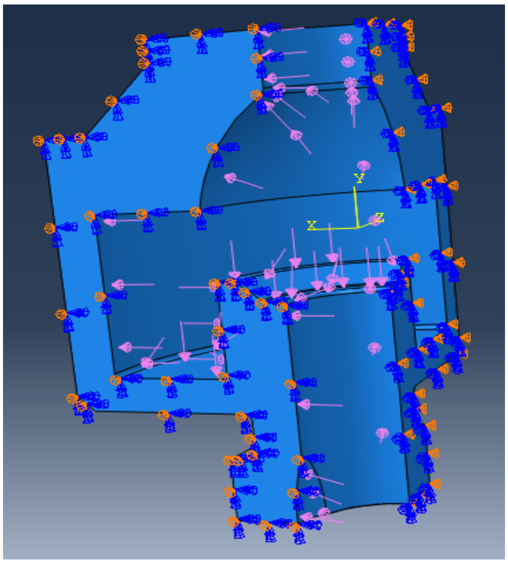

Fig 1. Loading and constraint model

Table 1. Technical parameters of FH35-35/70 annular BOP

Diameter	346mm
Dimensions	ϕ1270 × 1225mm
wall thickness	101mm
working pressure	35MPa
Strength test pressure	51MPa

3. Fatigue Life Analysis of Annular BOP Shell with Eccentric Wear Defect

3.1. Define Material Parameters

Fatigue tool is a fast fatigue analysis tool for analyzing complex structures based on the finite element analysis results. After the calculation of the finite element analysis part, the tool can be used for fatigue analysis. Fatigue is often used for various analyses of complex structures such as initial crack analysis, crack growth analysis, stress life analysis, etc. It also has a rich database of fatigue fracture materials, fatigue load history coefficient, and can visualize the fatigue life analysis results. Fatigue uses the stress fatigue theory, comprehensively considers the fatigue influence factors such as load, average stress and fatigue strength reduction factor, and carries out fatigue calculation according to the linear cumulative damage theory.

In the finite element analysis, the BOP material parameters, such as elastic modulus, yield strength, tensile strength, etc., are defined, and the stress and strain of the shell structure are calculated, and then the finite element analysis results are imported into Fatigue, as shown in Figure 2. The fatigue analysis only needs to redefine the elastic modulus, material type and S-N curve of the material.

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Material Field Variables	Table	
Density	7850	kg m^-3
Isotropic Secant Coefficient of Thermal Expansion		
Coefficient of Thermal Expansion	1.2E-05	C^-1
Isotropic Elasticity		
Derive from	Young's Modulus an...	
Young's Modulus	2E+11	Pa
Poisson's Ratio	0.3	
Bulk Modulus	1.6667E+11	Pa
Shear Modulus	7.6923E+10	Pa

Fig 2. Material definition interface diagram

When carrying out the fatigue analysis of the shell structure, it is necessary to know the material properties and S-N curve of the shell material. In the workbench material library, the S-N curve of the material is automatically estimated according to the material parameters (as shown in Figure 3). The use of the S-N curve reduces the workload and greatly improves the accuracy of the calculation.

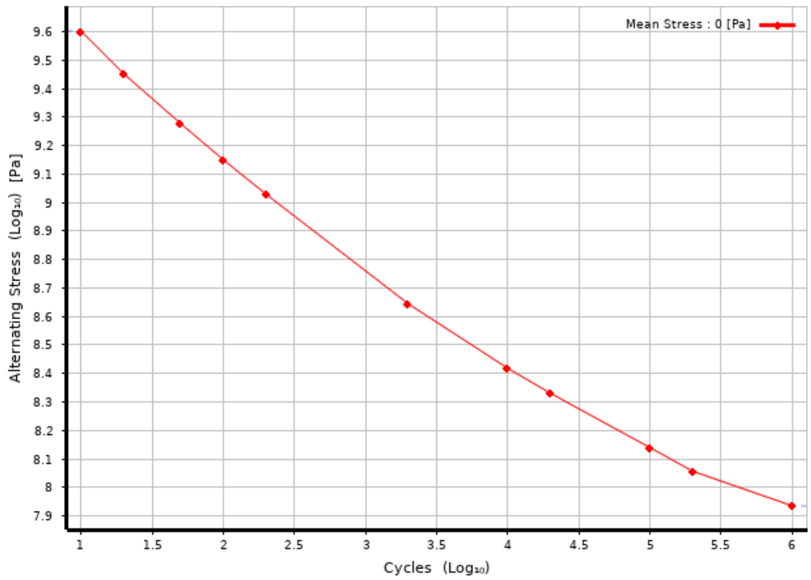

Fig 3. S-N curve interface diagram

3.2. Application of Load

The load on the annular BOP shell is uniformly distributed internal pressure. During finite element calculation and analysis, 35MPa uniformly distributed internal pressure is applied, while during fatigue analysis, cyclic internal pressure load is applied. The load spectrum is shown in Figure 4.

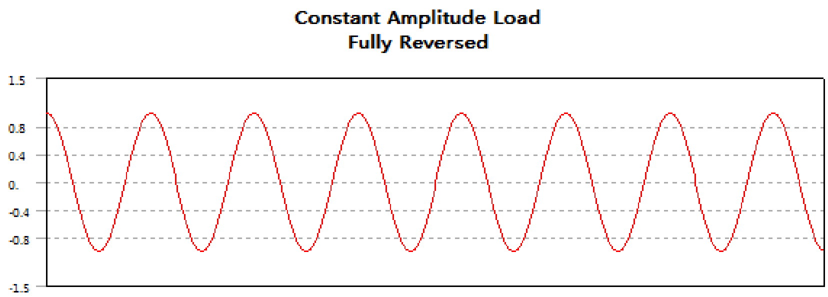

Fig 4. Fatigue analysis load spectrum

3.3. Life Analysis of Flawless BOP

The fatigue life of BOP shell is calculated by Palmgren-Miner cumulative damage rule, and the fatigue analysis results are extracted. As shown in Figure 5, observe the life distribution of the

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shell. It is assumed that the annular blowout preventer works under the rated condition every time, the minimum life of the shell occurs at the maximum equivalent stress of the shell, and the minimum life of the annular blowout preventer shell is 5203 pressure-bearing cycles, which is far greater than the 500 times specified in the standard.

According to the field survey, the number of BOP pressure tests used for each well is 8-10 times. In the 14-year service history of an annular BOP, the cumulative number of service wellhead is 22, and the BOP is opened and closed for about 18~20 times a year. The service life of the annular blowout preventer is much longer than 15a or 16a required by the industry standard according to the calculation of 20 pressure-bearing cycles.

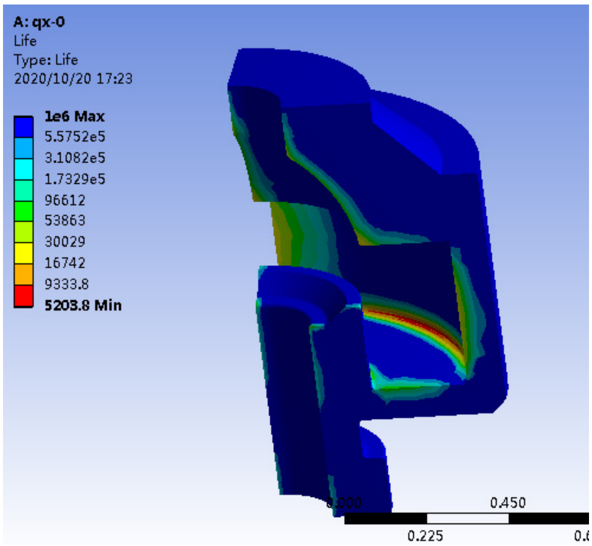
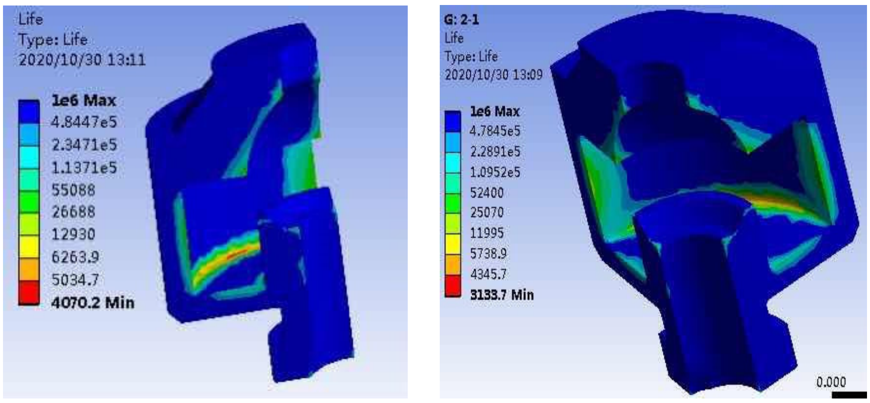


Fig 5. Life nephogram of defect-free annular BOP shell

3.4. Result Analysis

As shown in Figure 6, the BOP shell models with different eccentric wear depths of 1mm, 2mm, 3mm and 4mm are established, and the fatigue life of the BOP shell is analyzed by Palmgren-Miner cumulative damage rule, and the fatigue analysis results are extracted, and the distribution of the shell life is observed.

From the life nephogram of annular BOP at different wear depths, the corresponding fatigue life at different wear depths can be obtained, as shown in Figure 7.



a) Wear depth 1mm b)Wear depth 2mm

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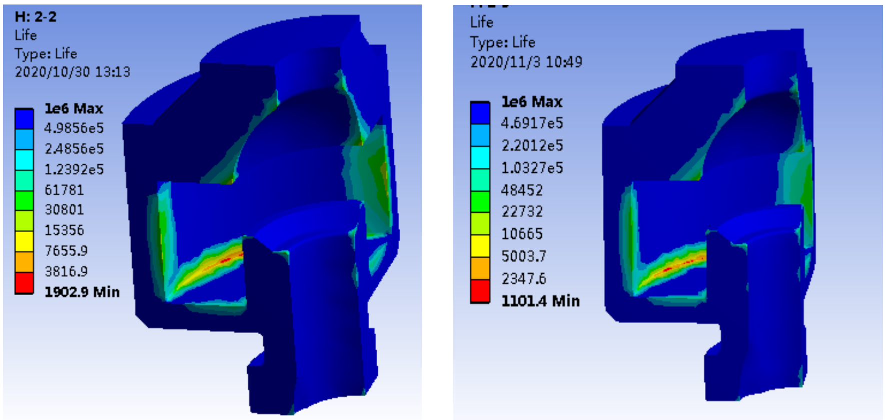

c) Wear depth 3mm d) Wear depth 4mm

Fig 6. Life nephogram of annular BOP shell under different wear depths

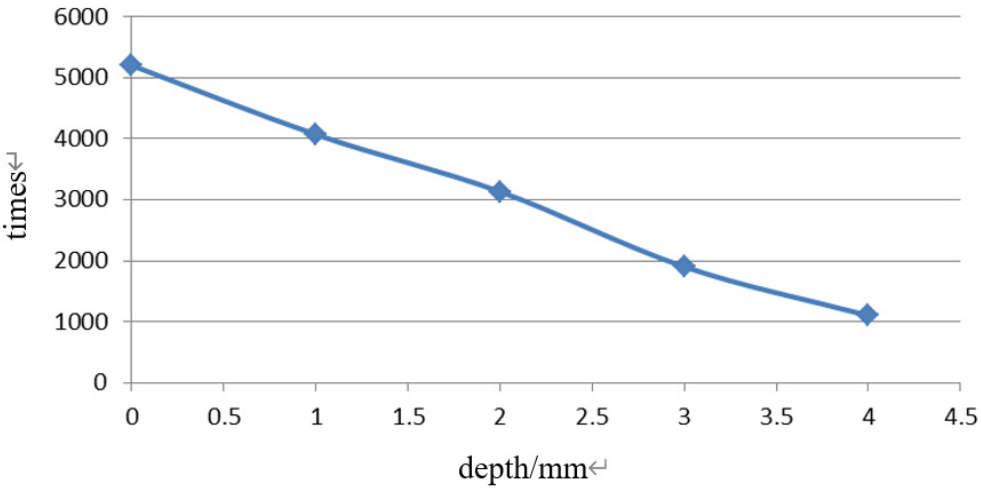

Fig 7. Life curve of BOP under different eccentric wear depth

It can be seen from Figure 7 that the eccentric wear depth has a significant impact on the fatigue life. The fatigue life shows a monotonic decreasing trend from the eccentric wear depth of 0~4mm, and the residual life decreases by the same extent when the defect increases to the same depth. Therefore, it can be inferred that when the eccentric wear depth in the same radius direction exceeds 5mm, the safety of BOP will be greatly reduced.

As shown in Figure 8, the eccentric wear length of 200 mm, 250 mm, 300 mm and 350 mm are selected respectively, and the BOP shell model with different eccentric wear length is established. The fatigue life of the BOP shell is analyzed by Palmgren-Miner cumulative damage rule, the fatigue analysis results are extracted, and the life distribution of the shell is observed.

From the life nephogram of annular BOP with different wear depths, the corresponding fatigue life under different wear lengths can be obtained, and its utility curve is drawn as shown in Figure 9.

It can be seen from Figure 9 that for eccentric wear defects, when the eccentric wear length is 200~350 mm, the influence of the eccentric wear length on the fatigue life is the largest. The fatigue life is monotonically decreasing from 0~250 mm, and the range of 200~350 mm tends to be flat. The minimum value is about 1500 pressure cycles. According to the calculation of 20 pressure cycles per year, the service life of the annular BOP is about 75a when the eccentric wear length is 200~350 mm.

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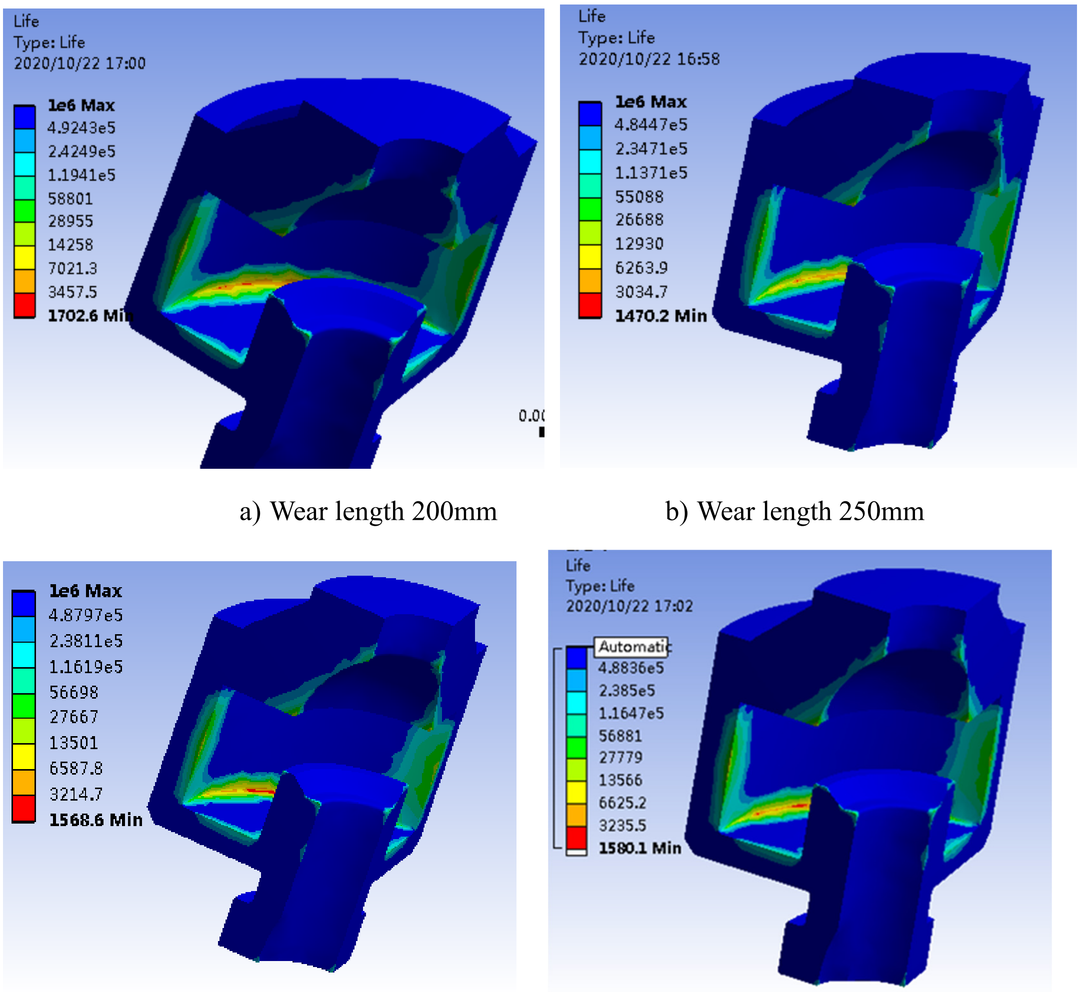

a) Wear length 200mm b) Wear length 250mm

c) Wear length 300mm d) Wear length 350mm

Fig 8. Life nephogram of annular BOP shell under different wear lengths

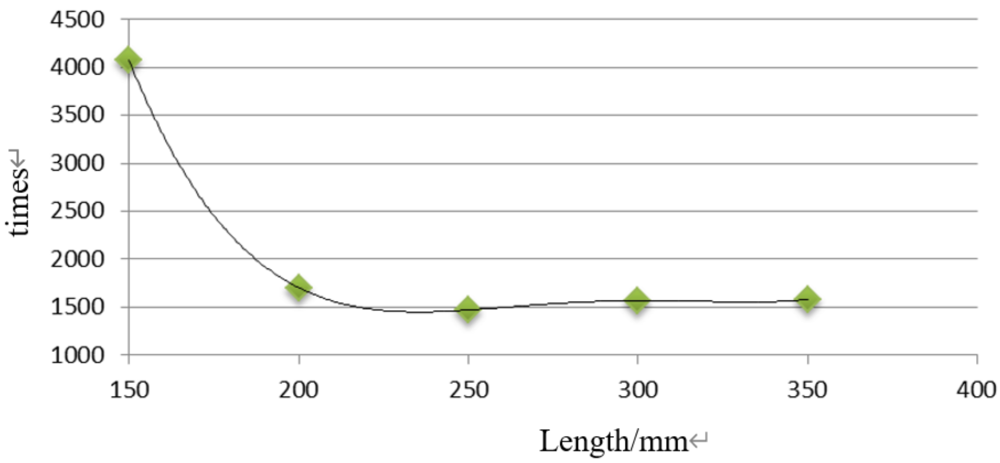

Fig 9. BOP utility curve under different eccentric wear length

4. Summary

(1) The life nephogram of BOP shell without eccentric wear defect is obtained by using the Fatigue tool. The life distribution of the shell is observed. The minimum life of the shell appears at the maximum equivalent stress of the shell. Moreover, the number of pressure-bearing cycles

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and service life of the annular BOP without eccentric wear defects calculated according to the fatigue life are far greater than those specified in the industry standards, and the impact of the cyclic pressure borne by the shell on the service life of the BOP is small;

(2) For the eccentric wear defect, the maximum impact on fatigue life is the eccentric wear length, followed by the eccentric wear depth. When the eccentric wear length is in the range of 200~350 mm, the maximum impact is when the eccentric wear depth is greater than 4 mm.

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